Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

VEGETATION AS A TOOL FOR THERMAL REGULATION OF URBAN MICROCLIMATE IN ARID REGIONS

H. Badache[1*], Dj. Alkama[2]

[1]LACOMOFA Laboratory, Department of Architecture,University Mohamed Khider, Biskra 07000, Algeria

[2]Department of Architecture, University 8 may 1945,Guelma 24000, Algeria

Received: 29 April 2020 / Accepted: 09 September 2020 / Published online: 01 January 2021

ABSTRACT

The city of Biskra is known by its hot and arid climate; its outdoor spaces know extremely high temperatures during the summer period, which affect thermal comfort, well-being, user's satisfaction in public spaces, such as the "Revolution's plaza" which known by considerable attendance and a particular design. This study, focuses on the role of the urban vegetation on the thermal regulation in the open space. The main purpose is to study the effect of vegetation on the urban microclimate of this space "Revolution plaza", through a site investigation, in order to measure the local climate and compare the results with weather's station data. After that, an improvement case is suggested by simulation by Envi-Met 4 software. The results show the significant effect of the trees and natural surfaces in decreasing the heat transfer and temperatures degrees; which provides a favorable microclimate in this open space.

Keywords: Vegetation; Arid climate; Public space; Simulation, hot region; Biskra.

Author Correspondence, e-mail: badache.hb@gmail.com

doi: http://dx.doi.org/10.4314/jfas.v13i1.2

1. INTRODUCTION

Urban vegetation is an essential component in the city; because of its advantages on the urban microclimate; it is an effective tool for sun protection and radiation's control. The foliage of a tree can filter from 60% to 90% of solar radiation [1]. Urban areas with pavement of (concrete, asphalt ...) are easier to be heated by solar radiation than the city's periphery, the temperature can be increased from 2 to 5°C in the city [2]. So, the vegetation is a very effective factor to improve the urban microclimate in public space. Plants in arid cities are used to reduce solar radiation, provide shade, increase evapotranspiration, improve the conditions of thermal comfort for pedestrians and reduce energy consumption [3]. In a semi-arid climate, the vegetation of the green facades acts as a buffer zone between the interior and exterior environment [4].

Recently, rapid urbanization of cities and the use of solid materials have a direct influence on the microclimate and increase the temperature degrees in arid regions. As a result of this urbanization, the natural surfaces are often replaced by solid surfaces such as asphalt and concrete, which increase the temperature. The increase in heating of the urban atmosphere compared to non-urbanized rural environment generates the urban heat island phenomenon (UHI), because of the use of building materials with low solar reflectivity, and the replacement of natural green surfaces by other solid surfaces [5]. Dark horizontal surfaces such as concrete paving and asphalt can reach 50 and 60 ° C in the early afternoon [6].

Several researches are interested to study the efficient of plant on the outdoor thermal comfort. A study in a urban park in Cairo, Egypt, results that the elements of the landscape serve to improve human comfort, the combination of vegetation and water improves the thermal environment and has brought users to report less dissatisfaction, also the use of "cold" materials is suggested to control the absorption of radiation in summer season [**7**]. The combination of the cool material and trees decreases the surface's temperature by 7°C at midday [8]. In order to keep surface's temperature as low as possible in hot and dry region in summer, a light-colored paving material should be used then [9]. A research in an urban park in Beijing results that trees in clusters with vegetation on the ground generate a higher cooling effect than trees in clusters without vegetation on the ground, and isolated trees, and a proper irrigation regime could improve the cooling effect of the herbs [10]. Also, shading has a very significant effect on reducing solar radiation of surfaces; designers must take into consideration the characteristics of shading to improve outdoors' thermal comfort, and mitigate the effect of the urban heat island [11]. Another research in a small green space of 0.24 ha in Lisbon; recorded a temperature difference of 6.9°C in the green space (Park) compared to its environmental zone during the summer period [12].

The city of Biskra is characterized by its hot and arid climate, it registers a flagrant increase in the degrees of temperature especially in the summer period in urban public spaces, this will generate an increase in climatic stress, warming of the microclimate, and discomfort ambiences for the users of these outdoor spaces. Users' comfort can indicate the success of public spaces, the thermal state of users of which plays an important role in the success of urban open spaces [13]. Therefore, it is necessary to ensure the best favourable climatic conditions in the public spaces of Biskra, in order to guarantee a good effectivity from these places, at the environmental, social, health and mental level of the inhabitants. The use of plants in these public spaces will provide a preferable and impeccable living environment.

This research focuses on the study of the effect of vegetation on the thermal regulation of revolution's plaza in Biskra city, by analysing the main climatic parameters during the summer, in order to assess the efficiency of vegetation and the effect of either mineral or natural paving materials on the microclimate. So, the aim of this study is to improve the local thermal environment of this plaza.

2. CASE STUDY AND METHODOLOGY

2.1. Study Area

The city of Biskra is located in the south-east of Algeria, at 34.80 North Latitude, and 5.73 East Longitude, it is characterized by its hot and arid climate, the temperature reaches maximum degrees in the month of July, with an average temperature of 43 °C. The phenomenon of evapotranspiration reaches its peak in July with 426 mm, noting an irregularity and a weak forecast (120 mm) [14].

The public space of Biskra has affected by several morphological transformations through the city's transformation. The green space has its origin in the dense vegetation of the palm grove. It has a double role, firstly, it is an economic resource, and secondly, it works as a bioclimatic envelope [15]. The palm grove and the Seguias were the mythical center of small human settlements; and places for meeting and gathering. Water was the generating element of the urban form, including the streams (Seguias) flowing along the street (Z'gag) and irrigating the palm gardens [16].

The Study area is a very important node (roundabout), known as a Revolution's plaza, located on a very important mechanical axis -Zaatcha- just next to the tunnel of Biskra, this node known by its very strong mechanical flow, and ensures good accessibility for the whole city. The site is divided to three quasi-triangular parts surrounding a large central circle (fig.1). The Revolution's plaza knows a great attendance, due to its strategic position, its vegetal cover and its design which offers preferable places for citizens' gathering in the city. Its vegetation varies between Ficus, Palm, and Acacia trees with different sizes and densities. It has a large fountain located in the central circle, which works occasionally. The paving materials in the terrain differ between: asphalt for mechanical tracks, granite and concrete for sidewalks and pedestrian crossings, and natural soil, and rarely the grass scattered here and there.

Fig.1. the Revolution's plaza

2.2. Methodoloy

The main objective of this research is to assess the effect of the urban vegetation on the thermal comfort and its principal environmental factors; the aim is to evaluate the effect of trees and plant on the thermal regulation and human thermal comfort in the open space in a hot and dry area like the revolution's plaza in the city of Biskra.

Before evaluating the thermal environment, the comfort criteria must be defined; which are: Temperature (air, radiant, surface) / Humidity / Air speed [17]. Therefore, among the key factors of human thermal comfort, there are the environmental factors, which must be taken in consideration for the design with the microclimate, these factors are (air temperature, relative humidity, air movement, and mean radiant temperature) [18].

Mean radiant temperature is defined as the uniform temperature of a black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure. It is considered as a spatial average of the temperature of surfaces surrounding the occupant. [19]. Radiant heat transfer is very important factor in determining thermal comfort, especially in open spaces [20].

The surface’s temperature has a significant effect on the average radiant temperature; whose effect of surface temperature is immediately linked to the nature, type, color, albedo and texture of surface materials (mineral or natural), which also, directly, influences on solar radiation in the space. So, these climatic parameters: Temperature (Ta - Ts - Tmrt), relative humidity (Rh), and wind speed (Ws) are considered the main parameters that influence outdoor thermal comfort.

In order to examine the effect of vegetation on outdoor thermal comfort, this research is based on two main steps:

Step A: Investigation in situ -Current Case-

After direct observations and measurements made in the site, especially during the second half of July -the hottest month in summer-, a typical day was chosen to represent the results collected on the site. Measurements (bi-hourly) were made to record the values of the climatic parameters (Ta, Rh, Ws) using a Testo 480 measuring device with two probes. Through three stations distributed in the site and distinguished between them by their paving materials, by their category and size of the plant, and by their orientation (Table.1).

Step B: Numerical Simulation -Optimisation Case-

The numerical simulation was made in order to record the values of different climatic parameters. The numerical simulation is done in two levels:

The first level was made in order to evaluate the values of the mean radiant temperature

(Tmrt) and the surface temperature (Ts) of the current case.

The second level of the numerical simulation is the optimization level, which is based on the modification and alternatives of improvement in an adequate and homogeneous manner in the whole study area (Table.2).

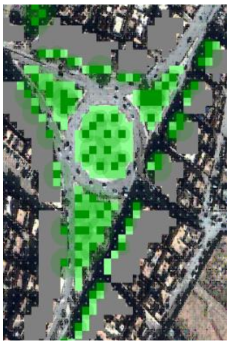
Table.1. Characteristics of measurements stations

Station	Characteristic	Fish Eye-Photo
S 1 	Orientation: North-West Material Ground: Soil Albedo: 0.18 Type of vegetation: Palm wachintognia, Grass, Ficus	
S 2 	Orientation: North-East Material Ground: Granit Albedo 0.15 Type of vegetation: Ficus, Acacia	
S 3 	Orientation: South-West Material Ground: Granit Albedo: 0.15 Type of vegetation: Ficus, Acacia	

A comparative study was chosen to distinguish the values of the climatic parameters between the three measuring stations, which aims to compare the microclimatic factors in the three stations, which are distinguished by the type, size, and density of the plant.

This research adopted the Envi-Met as simulation software. The ENVI-met model is made up by four main systems: soil, vegetation, atmosphere and building. Concerning natural soils, heat transfers and water vapor, all are considered while simple heat transfer is considered for sealed materials [21]. ENVI-met allows to analyse the impact of changes in urban design on the microclimate under different conditions. It simulates the interactions between surfaces, vegetation and the atmosphere [22].

Table.2. Modeling with alternatives of improvement

Cases	Alternatives of improvement
Current Case (A)   Improvement Case (B)  	- Replacing dark asphalt by a gray concert and the granite pavement by a light pavement –light concrete- - Densify the planting of vegetation in the southern part of the plaza (S3) - Addition of the water’s sources in the area, especially in the southern part (S3) -Choose trees with a high trunk to facilitate the vision of drivers and pedestrians - Choose trees with large crowns to provide a large shade area. - Choose trees that adapted to hot and arid climate like (Ficus, Acacia) - Choose the grass for paving in the three stations, also natural soil for surfaces of S2 and S3.

3. RESULTS AND DISCUSSION

3.1. Experimentation & measurements

The Results of experimentation and measurements are treated according to the comparative method to distinguish and compare between the results of measurements recorded in the (site) of the current case and the data which was brought from the meteorological station.

3.1.1. Measured Air Temperature (Ta)

Vegetation serves to decrease the air temperature by shading the surfaces, and it reduces solar heat by evapotranspiration of plants [23]. This justifies the degrees of air temperature measured in the plaza in the three stations (fig.2); which are lower than the meteorological data, a difference of 3°C recorded between the values of station 01 and the data of the meteorological station, due to the effect of the shade of the plant, also noting that the temperature values of station 01 is less than the other two stations at 2 ° C difference recorded at 14h (peak time), this is due to the minimum reflectivity of heat radiation from the natural surface (soil surface) in the station 01 than the two other stations with a solid mineral surface.

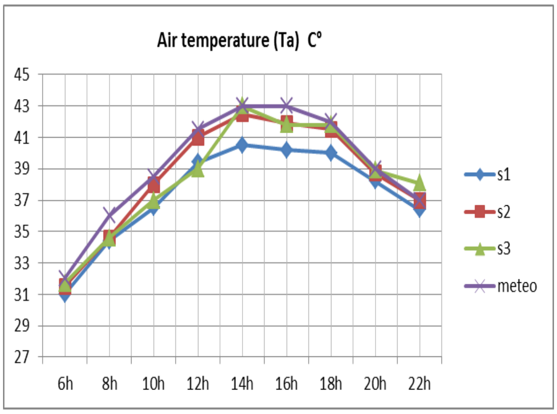


Fig.2 Measured Air Temperature (Ta)

3.1.2. Measured Relative Humidity (RH)

The results show the relative humidity values of the weather station are higher compared to the measured data because of the high degrees of the temperature of the weather station site (fig.3). The humidity values between the three measuring stations are very close all day except that the greatest differences are recorded during the period (12 h to 18h). A difference of 3% is recorded at 14h between station 01 and station 03 because of the high temperature, especially in the afternoon, which reinforces the effect of the evapotranspiration of plants and the natural soil of station 01. According to [24], vegetation can decrease the rate of relative humidity by 2.79%; the difference is related to the stomatal resistance of leaves.

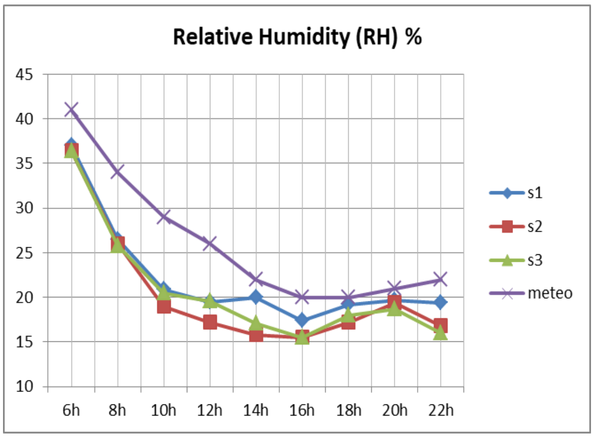


Fig.3. Measured Relative Humidity (RH)

3.1.3.Measured Wind Speed (Ws)

A big difference is underlined between the values recorded in study area (at a height of 1.5m) compared to the values of the recorded meteorological station (with high height) which is located in a vast area without any mineral or naturel obstacle. As well as the effect of trees and the heights of surrounding buildings contribute to the reduction of the air speed in the site. The values of wind speed in the three stations are very approximate with a peak recorded at 16h but it remains stable most of the day with a slight increase recorded during the afternoon period (fig.4).

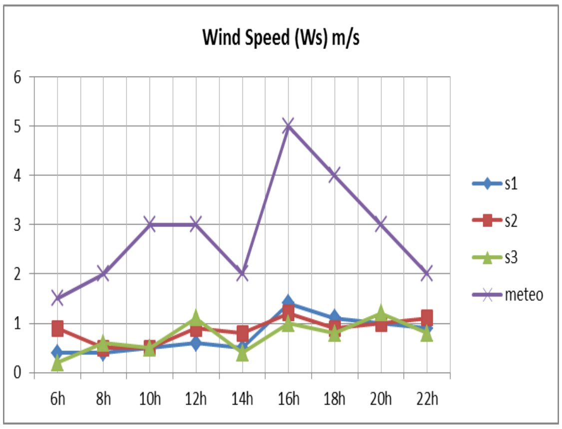


Fig 4. Measured Wind Speed (Ws)

3.2. Results of numerical simulation

Numerical simulation is mainly done to check the effectiveness of the improvements that have been made during optimization process, -which are explained in step B of Methodology-; these modifications are made in an equal and homogeneous way for all of the study area.

3.2.1. Surface's temperature (Ts)

Simulation results of the surface's temperature in the three stations follow the same curve; they progressively increased from 6 h until 18 h when it registers a peak about 37°C. The results of the simulation (fig.5) of the optimization case are lower than the real case for station 01, which show two curves are very close; because the current case is already has a natural surface and recorded a lower temperature than the other stations. For station 02 (North-East) a difference is recorded up to 2 °C. On the other hand, station 03 that located in the south and show a difference that can reach up to 1 °C. These results are confirmed by other studies. For [25], the surface temperature of a humid grass exposed to the sun is much lower than that of a mineral surface even if it has a high albedo. Shaded surfaces have surface temperatures lower than air temperature; and they are 40% cooler than surfaces exposed to solar radiation. And the relation between surface temperatures and surface albedo, demonstrating that low temperatures are recorded on high albedo surfaces [26]. Moreover, increasing the albedo by using light coloured materials will reduce air temperature and decrease short-wave radiation's absorption [27].

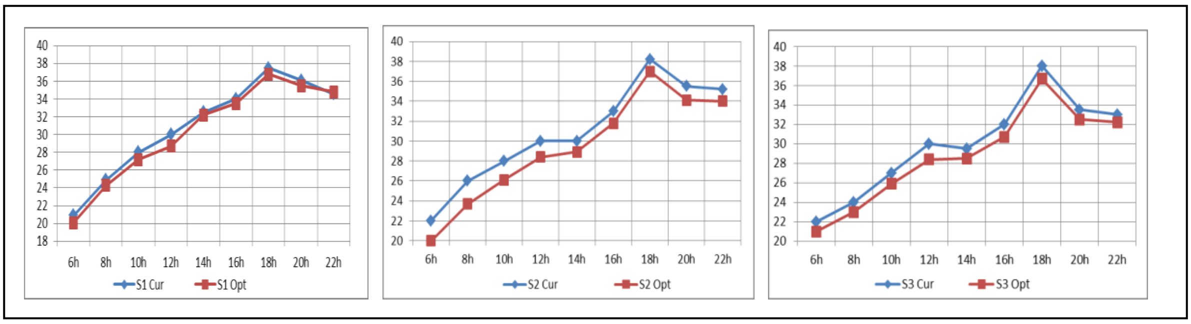


Fig.5. Surface's Temperature in Three stations

3.2.2. Mean Radiant Temperature (Tmrt)

The mean radiant temperature (Tmrt) is one of the most important parameters to control thermal comfort. Simulation's results of the current case and the optimized case show that the values of Tmrt-Opt decrease throughout the day compared to the values of Tmrt-Cur especially during the morning, including a difference of more than 4 °C recorded at 10 h in station 01 and 02 located in the northern part of the plaza (fig.6). On the other side, station 03 (to the south) recorded values which are very close in both cases, since this area is exposed to the sun all day, but the optimization values remain less than the current case. In general, the degrees of Tmrt record a Peak (around 51 °C) during the afternoon period, and then they begin to decrease from 16h until night with the same curve for the three stations. According to the study of [28], after an optimal proposal of optimisation in Ibn Badis's plaza in Biskra, it records an average of 33 ° C of radiant temperature all the day, except, at midday when it became 54.1 ° C.

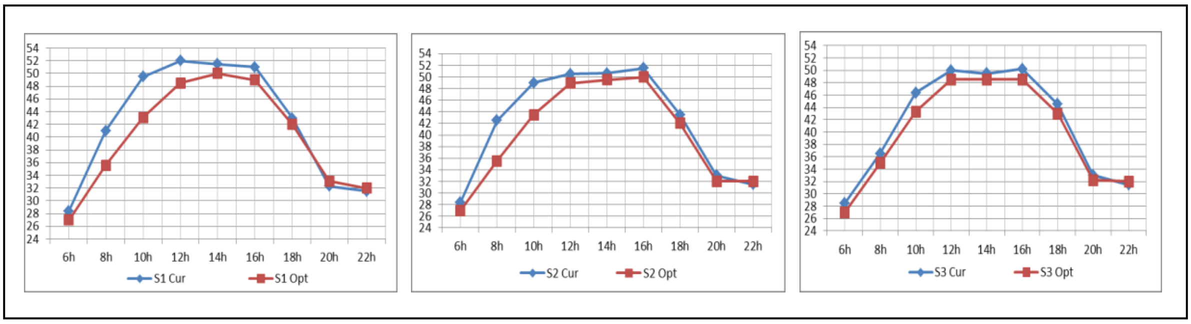


Fig.6. Mean Radiant Temperature in Three stations

3.2.3. Air temperature (Ta)

After improving and replacing the pavement material by a natural and white covered material, as well as the vegetation's densification, and through the comparison between the values of Air temperature according to three levels A/ measurement results of the current case, B/ result of the optimization case. C/ meteorological data in the three measurement stations (fig.7), this comparison shows a significant decrease in the values of Ta after optimization, particularly in the hottest period of the afternoon, an average is recorded from 8h at 20h between [2°C to 4.5°C]. Also at 14-a peak of 5°C- is recorded in station 02(North-east). As well as the optimization results are very close for the three stations, which show a feeling of equal comfort in the space and that of the equal distribution of vegetation throughout the surface. This result agrees with the study of [29], which registers a maximum of daytime cooling effect of the green cover which was 4.5°C in reference to old town. According to [30], the maximum difference between the temperatures of the leaves and the air, vary from 9°C for a tree above an asphalt surface to 4°C when it is above a grass.

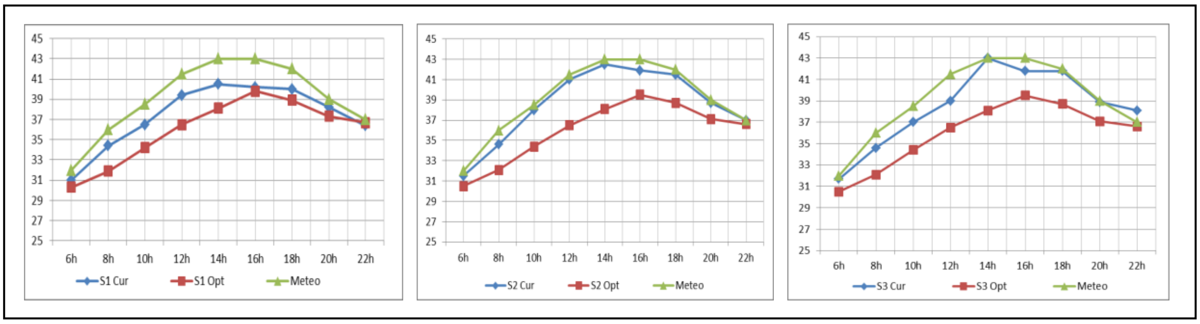


Fig.7. Air Temperature in Three stations

3.2.4. Relative Humidity (RH)

The relative humidity values after optimization are very high (fig.8), they almost reach the meteorological data; an average of [3%- 8%] was recorded between the current case and the optimized case, with a peak recorded at 10h. This increasing in humidity is the result of the increase in the effect of the evapotranspiration of the dense and variation of the vegetal cover and the additional of water source and a humid pavement –grass- which promote relative humidity, the minimum value in the three levels (A / current case, B / optimization case, C / Meteo) is recorded at 16h. The result of the study of [31], showed that also small green areas can regulate the microclimate by reducing the temperature by 1to 3°C on average and increase humidity by 2 to 8%. According to [32], the optimization of air temperature and relative humidity, recorded a difference about 3 degrees for (Ta) and 4.4% for (RH).

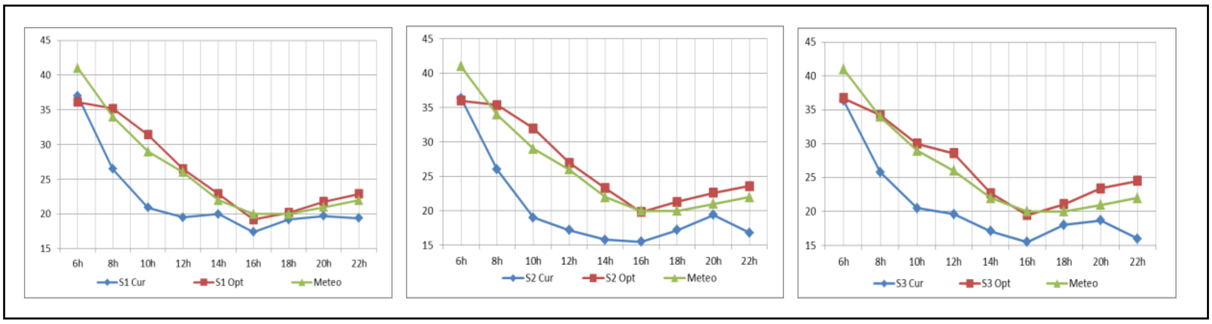


Fig.8. Relative Humidity in Three stations

3.2.5. Wind Speed (Ws)

The weather values remain higher compared to the other results (fig.9), because its data comes from the airport outside the city, so the results of two cases remain less than the weather data, this reflects the effect of urban fabric which weakens the speed of air in the city. The air speed values after optimization are very close to those obtained from the measurements, while recording a small increase in the optimization results due to the effect of atmospheric pressure caused by the phenomenon of evaporation of plants. The evapotranspiration from the soil and the vegetation, increases the air humidity. The trees decrease wind speed and filter the Saharan dust [33].

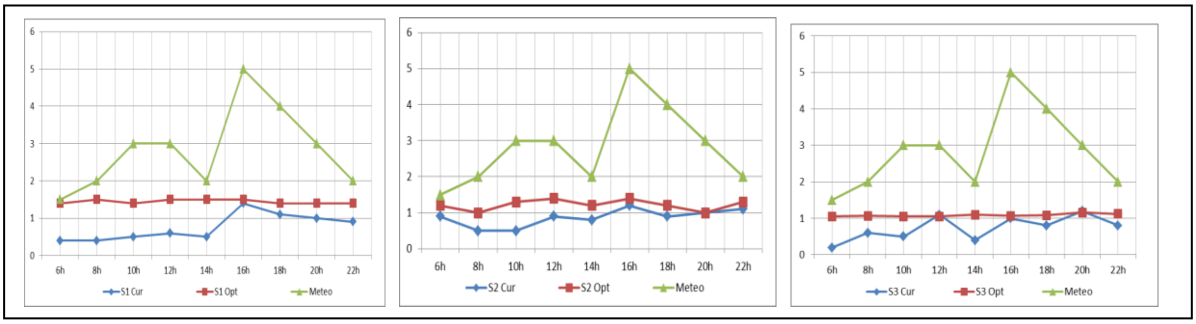


Fig.9. Wind Speed in Three stations

4. CONCLUSION

Through this research which is mainly based on the vegetation's impact on thermal regulation and on the urban microclimate in the city of Biskra, characterized by its hot and arid climate, we can deduce that: the presence of vegetation is very important in public space as in the case of the "Revolution's plaza" which is very popular and well attended, especially in summer, the vegetation in the plaza improves the comfort of users and affects the surfaces reflecting heat. From the results of site investigation of the current case, as well as the numerical simulation, it is emphasized that: the density, the size, and the location of the trees can reduce the degrees of air temperature up to 5°C at 14h -the peak-, and 4°C at 10h –the peak- for Tmrt after the optimization, and increase the relative humidity with an average of [3%-8%]. The natural covering of the surface –grass- enhances the effect of evapotranspiration and also serves to decrease the surface's temperatures, and the same for the Mean radiant temperature.

In order to enhance the effect of vegetation in open space, especially in hot and dry climate, it is recommended to:

- Choose trees with high trunk -under the canopy -with height that above 2m; to facilitate the vision of pedestrians or drivers, and with a large crown to provide large shading area.
- Choose trees that adapted to Biskra's hot and arid climate such as Ficus, Acacia, Eucalyptus which can reach heights of over 15m and crown width of 8m.
- Densify and orient the planting of trees towards the southern part in order to reduce hot winds and to purify dust that comes from sand winds.
- Add moving water elements; this will reinforce the effect of plant's evapotranspiration.

- Use a natural soil and cool materials for the pavement's surface. A high albedo surface and a planting of urban trees are inexpensive tools that can be used to reduce summer's temperature [34].

Therefore, it is important to highlight the plant factor in the design and urban planning, in order to properly master the use of vegetation to improve the microclimate in urban public spaces and therefore the improvement of users' quality of life while using such spaces in hot and arid regions.

5. REFERENCES

[1] De Herde A & Liébard. Traité d'architecture et d'urbanisme bioclimatiques. Edition, Paris Observ'ER. 2005. pp 22-368.

[2] Han S-G, Mun S-H, Huh J-H. Changes of the microclimate and building cooling load due to the green effect of a restored stream in Seoul. Proceedings: Building Simulation 2007

[3] Obiakor M. O, Ezeonyejiaku C.D, & Mocbo T.C. Effects of Vegetated and Synthetic (Impervious) Surfaces on the Microclimate of Urban Area. J. Appl. Sci. Environ. Manage. March, 2012 Vol. 16 (1) 85 – 94

[4] Benhalilou K, Abdou S, Djedjig R. Experimental investigation of hygrothermal behaviour of direct green facades under semi aride climate. J Fundam Appl Sci. 2020, 12(1), 213-229

[5] Kantzioura A, Kosmopoulos P, Zoras S. Urban surface temperature and microclimate measurements in Thessaloniki. Int.J. Energy and Buildings 44 (2012) 63–72

[6] Emmanuel R, Johansson E. Influence of urban morphology and sea breeze on hot humid microclimate: the case of Colombo, Sri Lanka. Climate Research, Vol. 30: 189–200, 2006.

[7] Mahmoud A.H. Analysis of the microclimatic and human comfort conditions in an urban park in hot and arid regions. Building and Environment 46 (2011) 2641-2656. doi:10.1016/j.buildenv.2011.06.025

[8] Adeb Qaid A, Dilshan R.O, Elmira J, Norhashima A.M, Ismail S, Mohd Hamdan A. Urban surface temperature behaviour and heat island effect in a tropical planned city. Theor Appl Climatol. Springer-Verlag Wien 2014, doi 10.1007/s00704-014-1122-2

[9] Johnsson E. Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. Building and Environment 41 (2006) 1326–1338. doi:10.1016/j.buildenv.2005.05.022

[10] Amani-Beni M, Zhang B, Xie G-d, Xu J. Impact of urban park's tree, grass and waterbody on microclimate in hot summer days: A case study of Olympic Park in Beijing, China.Urban Forestry and Urban Greening. doi 10.1016/j.ufug.2018.03.016

[11] Ridha S, Urban heat Island mitigation strategies in an arid climate. In outdoor thermal comfort reacheable. These de doctorat. Civil Engineering. INSA de Toulouse, 2017, pp.120–143

[12] Oliveira S, Andrade H, Vaz T. The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon, Building and Environment 46 (2011) 2186e2194, doi:10.1016/j.buildenv.2011.04.034

[13] Aljawabra F, Nikolopoulou N. Influence of hot arid climate on the use of outdoor urban spaces and thermal comfort. Int.J. Intelligent Buildings International 2 (2010), 00–00

[14] Mazouz S. La ville et le désert- le Bas Sahara algérien. Sous la direction de Marc Côte. Edition Karthala. 2005.

[15] Badache H. L'espace public entre conception et usage : Cas des jardins publics de Biskra. Mémoire de magister. Université de Biskra. 2014. pp. 133–296

[16] Alkama D. Analyses typologiques de l'habitat, cas de Biskra. Thèse de magister Université de Biskra. 1995.

[17] ASHRAE, ANSI/ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy. 2004. pp.13–26

[18] Setaih K, Hamza N, Townshend T. Assessment of outdoor thermal comfort in urbain microclimate in hot arid areas.3 Proceedings of BS2013.13th Conference of International building serformance simulation association, Chambéry, France. August 26-28.2013.

[19] ASHRAE. ASHRAE Fundamentals Handbook 2001 (SI Edition) American Society of Heating, Refrigerating, and Air-Conditioning Engineers;2001.

[20] Ahriz.A, Zemmouri.N, Fezzai.S. SPUCAL_mrt as a new model for estimating the mean radiant temperature in arid lands. Energy Procedia 74 (2015) 273 – 280

[21] Yang X, Zhao L, Bruse M & Meng Q. Evaluation of a microclimate model for predicting the thermal behaviour of different ground surfaces. Int. J. Building and Environment 60 (2013) 93-104.

[22] Bruse M, Fleer F. Simulating surface–plant–air interactions inside urban environments with a three-dimensional numerical model. Int. J. Environmental Modelling & Software 13 (1998) 373–384

[23] Dimoudi A, Nikolopoulou.M, Vegetation in the urban environment: microclimatic analysis and benefits, Energy and Buildings, 35 (2003) 69-76.

[24] Ballout A, Lacheheb D.E.Z, Bouchahm Y. Improvement of Thermal Comfort Conditions in anUrban Space (Case Study: The Square of Independence, Sétif, Algeria). European Journal of Sustainable Development (2015), 4, 2, 407-416. Doi:10.14207/ejsd.2015.v4n2p407

[25] Izard J.L. Temperarures de surfacs d'une pelouse dans ub parc urbain. EnviroBAT-Méditerranée, octobre 2006.

[26] Chatzidimitriou A, Chrissomallidou N, Yannas S. Ground surface materials and microclimates in urban open spaces PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland, 6-8 September 2006.

[27] Bourbia F, Awbi H.B. Building cluster and shading in urban canyon for hot dry climate Part 2: Shading simulations. Renewable Energy 29 (2004) 291–301, doi: 10.1016/S0960-1481(03)00171-X

[28] Hanafi A, Alkama Dj. Stratégie d'amélioration du confort thermique d'une place publique d'une ville saharienne 'Biskra/Algérie. Revue des Energies Renouvelables Vol. 19 N°3 (2016) 465 - 480

[29] Hamida B, Ameur R. The Effects of Green Spaces (Palme Trees) on the Microclimate in Arid Zones, Case Study: Ghardaia, Algeria. Architecture Research 2012, 2(5): 60-67. DOI: 10.5923/j.arch.20120205.01

[30] Vinet J. Contribution _a la mod_elisation thermo-a_eraulique du microclimat urbain. Caractérisation de l'impact de l'eau et de la végétation sur les conditions de confort en espaces extérieurs. These de Doctorat. Université de Nantes, 2000. pp 74–245

[31] Grilo F, Pinho P, Aleixo C, Catita C, Silva P, Lopes N, Freitas C, Santos-Reis M, McPhearson T, Branquinho C. Using green to cool the grey: Modelling the cooling effect of green spaces with a high spatial resolution. Science of the Total Environment 724 (2020) 138182 . Doi.org/10.1016/j.scitotenv.2020.138182

[32] Louafi Bellara S, Abdou A. Vegetation effects on urban street microclimate and thermal comfort during overheated period under hot and dry climatic conditions. Journal of New Technology and Materials**,** JNTM**.** Vol. 06, N°02 (2016)87-94**.**

[33] Ali-Toudert F, Djenane M, Bensalem R, Mayer M. Outdoor thermal comfort in the old desert city of Beni-Isguen, Algeria. Climate Research. Vol. 28: 243–256, 2005

[34] Akbari H. Potentials of urban heat island mitigation. International Conference “Passive and Low Energy Cooling for the Built Environment, Santorini”, Greece. May 2005.

How to cite this article:
Badache H, Alkama Dj. Vegetation as a tool for thermal regulation of urban microclimate in arid regions. J. Fundam. Appl. Sci., 2021, *13(1), 23-39.*